6. RISK CHARACTERIZATION

Risk characterization is the final step in the risk quantification process, combining the information developed in the toxicity assessment (Section 3) and the exposure point concentrations (Section 4). Risk characterization is the estimate of potential carcinogenic and noncarcinogenic effects of constituents of potential concern (COPCs) over a lifetime of exposure. In this report, the risk from potential carcinogenic effects resulting from exposure to site-related COPCs is presented as the incremental lifetime cancer risk (ILCR). The risk of potential noncarcinogenic toxic effects is presented as the hazard index (HI).

Section 6.1 and Appendix B present the methods and results of the quantitative exposure assessment. Section 6.2 describes the methodology employed to characterize potential carcinogenic and noncarcinogenic risks. Section 6.3 presents the risks calculated for the Parcel A post-demolition exposure scenarios.

6.1 EXPOSURE QUANTIFICATION

The exposure assessment process quantifies the magnitude, frequency, and duration of exposure for those populations and pathways selected for quantitative evaluation in the conceptual exposure model (CEM, Section 4). The following sections give standard equations for estimating human intake and subsequent risk associated with the selected exposure pathways. The equations, exposure parameters, and parameter values were taken from EPA's Risk Assessment Guidance for Superfund (RAGS) and Exposure Factors Handbook (EPA 1989a, 1990a). The exposure parameters for each receptor under study are presented in Table 6-1, below.

Exposures were calculated for all receptors based on the construction and commercial/industrial exposure scenarios. On the following pages, the on-site construction worker is used as an example to illustrate the calculation of exposure to benzene through applicable pathways.

TABLE 6-1
RECEPTOR EXPOSURE PARAMETERS

		On-Site Receptors		
Pathway	Parameter	Construction Worker	Commercial/ Industrial Worker, RME	Commercial/ Industrial Worker, Upper Bound
Inhalation of Gases	IR - Inhalation Rate (m^3/h)	2.5	0.83	0.83
	EF - Exposure Frequency (d/y)	250	125	125
	ED - Exposure Duration (y)	1	25	25
	ET - Exposure Time, Outdoors (h/d)	8	0	4
	ET - Exposure Time, Indoors (h/d)	0	8	4
	BW - Body Weight (kg)	70	70	70
	AT - Averaging Time -car. (d)	25,550	25,550	25,550
	AT - Averaging Time - noncar. (d)	365	9,125	9,125
Inhalation of Particulate	IR - Inhalation Rate (m^3/h)	2.5	NA	0.83
	RFP - Respirable Fraction	0.5	↑	0.5
	EF - Exposure Frequency (d/y)	250	|	125
	ED - Exposure Duration (y)	1	|	25
	ET_O - Exposure Time, Outdoors (h/d)	8	|	4
	BW - Body Weight (kg)	70	|	70
	AT - Averaging Time -car. (d)	25,550	↓	25,550
	AT - Averaging Time - noncar. (d)	365	NA	9,125
Incidental Ingestion of Soil	IR - Ingestion Rate (mg/d)	480	NA	50
	EF - Exposure Frequency (d/y)	250	↑	125
	ED - Exposure Duration (y)	1	|	25
	BW - Body Weight (kg)	70	|	70
	AT - Averaging Time - car. (d)	25,550	|	25,550
	AT - Averaging Time - noncar. (d)	365	↓	9125
	CF - Conversion Factor (kg/mg)	1.00E-06	NA	1.00E-06
Dermal Contact with Soil	SA - Surface Area (cm^2/d)	5800	NA	2020
	ABS - Absorption Coefficient	csv	↑	csv
	AF - Adherence Factor (mg/cm^2)	1	|	1
	ED - Exposure Duration (y)	1	|	25
	EF - Exposure Frequency (d/y)	250	|	125
	BW - Body Weight (kg)	70	|	70
	AT - Averaging Time - car. (d)	25,550	|	25,550
	AT - Averaging Time - noncar. (d)	365	↓	9125
	CF - Conversion Factor (kg/mg)	1.00E-06	NA	1.00E-06

TABLE 6-1
RECEPTOR EXPOSURE PARAMETERS
(CONTINUED)

		Off-Site Receptors		
Pathway	Parameter	Commercial/ Industrial Worker	Resident Adult	Resident Child
Inhalation of Gases	IR - Inhalation Rate (m^3/h)	0.83	0.83	0.6
	EF - Exposure Frequency (d/y)	125	350	350
	ED - Exposure Duration (y)	25	30	6
	ET - Exposure Time (h/d)	8	24	24
	BW - Body Weight (kg)	70	70	15
	AT - Averaging Time -car. (d)	25,550	25,550	25,550
	AT - Averaging Time - noncar. (d)	9,125	10,950	2,190
Inhalation of Particulate	IR - Inhalation Rate (m^3/h)	NA	NA	NA
	RFP - Respirable Fraction	↕	↕	↕
	EF - Exposure Frequency (d/y)			
	ED - Exposure Duration (y)			
	ET - Exposure Time (h/d)			
	BW - Body Weight (kg)			
	AT - Averaging Time -car. (d)			
	AT - Averaging Time - noncar. (d)	NA	NA	NA
Incidental Ingestion of Soil	IR - Ingestion Rate (mg/d)	NA	NA	NA
	EF - Exposure Frequency (d/y)	↕	↕	↕
	ED - Exposure Duration (y)			
	BW - Body Weight (kg)			
	AT - Averaging Time - car. (d)			
	AT - Averaging Time - noncar. (d)			
	CF - Conversion Factor (kg/mg)	NA	NA	NA
Dermal Contact with Soil	SA - Surface Area (cm^2)	NA	NA	NA
	ABS - Absorption Coefficient	↕	↕	↕
	AF - Adherence Factor (mg/cm^2)			
	ED - Exposure Duration (y)			
	BW - Body Weight (kg)			
	AT - Averaging Time - car. (d)			
	AT - Averaging Time - noncar. (d)			
	CF - Conversion Factor (kg/mg)	NA	NA	NA

NOTES:
car. = carcinogenic
noncar. = noncarcinogenic
csv = constituent specific value
NA = Not Applicable

SOURCES:
RAGS (EPA 1989a)
Exposure Factors Handbook (EPA 1990a)

The exposure pathways of concern for the construction worker are: 1) inhalation of VOCs and particulate, 2) incidental ingestion of soil, and 3) dermal contact with soil. The example calculation methodology applies to all receptors associated with the Parcel A exposure scenarios; however, appropriate exposure parameters for other receptors would be substituted where applicable.

6.1.1 Air Exposures - Inhalation

Equation 6-16 from RAGS (EPA 1989a) was used to quantify intake from the inhalation pathway:

$$I_a = (C_a)(IR)(ET)(EF)(ED) / (BW)(AT) \qquad (6\text{-}1)$$

where

I_a	=	intake from inhalation of a COPC in air (mg/kg-d)
C_a	=	concentration of COPC in air (mg/m^3)
IR	=	inhalation rate (m^3/h)
ET	=	exposure time (h/d)
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg)
AT	=	averaging time (d), ED x 365d/y (noncarcinogens), 70y x 365d/y (carcinogens)

The COPC concentration in air, C_a, was calculated separately for the construction and commercial/industrial emissions cases, as follows:

Construction Emissions Case

$$C_a = (C_s)(1/VF + 1/PF) \qquad (6\text{-}2)$$

C_s	=	concentration of COPC in soil (mg/kg), from Table 5-1
VF	=	volatilization factor (kg/m^3), from Table 5-4

PF = particulate attenuation factor, 4.77×10^9 kg/m^3

Commercial/Industrial Emissions Case

$$C_a = C_i + C_o \qquad (6\text{-}3)$$

C_i = modeled indoor air concentration (mg/m^3), from Table 5-7

C_o = maximum modeled on-site COPC concentration (mg/m^3), from Table 5-6

As mentioned, the on-site construction worker's exposure to benzene is used as an example. The construction worker's intake (I_a) resulting from inhaling air hypothetically containing 1 milligram benzene per cubic meter air (C_a) is calculated as follows (see Table 6-1 for exposure parameters and sources). The inhalation rate (IR) for an active adult is 2.5 cubic meters per hour. The total exposure time (ET) is 8 hours per day for on-site exposures. The exposure duration (ED) is 1 year, and the exposure frequency (EF) is 250 days per year. The body weight (BW) for the adult resident is 70 kilograms. Since benzene is a carcinogen, the exposure is averaged over a 70-year lifetime (AT = 25,550 d). The exposure would be averaged over the period of exposure for all noncarcinogenic exposures (AT = ED x 365). Substituting these values into Equation 6-1 yields:

$$I_a = (1.0\ mg/m^3)(2.5\ m^3/h)(8\ h/d)(250\ d/y)(1\ y) / (70kg)(25550\ d) \qquad (6\text{-}4)$$

or

$$I_a = 2.80 \times 10^{-3}\ mg/kg\text{-}d$$

Appendix B presents the complete calculation sheets for inhalation exposures.

6.1.2 Soil Exposures - Incidental Ingestion

Equation 6-14 from RAGS (EPA 1989a) was used to quantify intake from the ingestion pathway:

$$I_{si} = (C_s)(IR)(CF)(FI)(EF)(ED) / (BW)(AT) \qquad (6\text{-}5)$$

where

I_{si}	=	intake from incidental ingestion of soil for a COPC (mg/kg-d)
C_s	=	concentration of COPC in soil (mg/kg), from Table 5-1
IR	=	ingestion rate (mg/d)
CF	=	conversion factor, 10^{-6} kg/mg
FI	=	fraction ingested from COPC source (unitless)
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg)
AT	=	averaging time (d), ED x 365d/y (noncarcinogens), 70y x 365d/y (carcinogens)

Using the on-site construction worker's exposure to benzene as an example, intake (I_{si}) resulting from ingestion of soil hypothetically containing 1 milligram benzene per kilogram soil (C_s) is calculated as follows (see Table 6-1 for exposure parameters and sources). The reasonable maximum ingestion rate (IR) of soil for construction activities is 480 milligrams per day with a fractional intake (FI) of 1. The exposure frequency (EF) is 250 days per year, and the exposure duration (ED) is 1 year. The body weight (BW) for an adult is 70 kilograms. For potential carcinogenic effects, the intake is averaged over a 70-year lifetime (AT = 25,550 d). For potential noncarcinogenic hazards, the intake is averaged over the actual duration of exposure (AT = ED x 365 d). For the construction worker, the exposure duration is less than 1 year and averaged over 126 days. Substituting these values into Equation 6-5 yields:

$$I_{si} = (1\ mg/kg)(480\ mg/d)(10^{-6})(1)(250\ d/y)(1\ y) / (70\ kg)(25550\ d) \qquad (6\text{-}6)$$

or

$$I_{si} = 6.71 \times 10^{-8}\ mg/kg\text{-}d$$

Appendix B has complete calculation sheets for exposure through incidental ingestion of soil.

6.1.3 Soil Exposures - Dermal Contact

Equation 6-15 from the RAGS (EPA 1989a) was used to quantify intake from the dermal contact pathway:

$$I_{sd} = (C_s)(SA)(CF)(AF)(ABS)(EF)(ED) / (BW)(AT) \qquad (6\text{-}7)$$

where

I_{sd}	=	intake from dermal contact with soil for a COPC (mg/kg-d)
C_s	=	concentration of a COPC in soil (mg/kg), from Table 5-1
SA	=	skin surface area in contact with soils (cm^2/d)
CF	=	conversion factor, 10^{-6} kg/mg
AF	=	soil-to-skin adherence factor (mg/cm^2)
ABS	=	COPC-specific absorption factor (unitless), from Table 6-2
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg)
AT	=	averaging time (d), ED x 365d/y (noncarcinogens), 70y x 365d/y (carcinogens)

Continuing with the construction worker/benzene example, intake (I_{sd}) resulting from dermal contact with soil hypothetically containing 1 milligram benzene per kilogram soil is calculated as follows (see Table 6-1 for exposure parameters and sources). The adult skin surface area (SA) assumed exposed during construction activities is 5,800 square centimeters per day with a soil-to-skin adherence factor (AF) of 1.0 and a COPC-specific absorption factor (ABS) of 1.0×10^{-1} (Table 6-2 presents the absorption factors for each COPC evaluated in this report). The exposure frequency (EF) is 250 days per year, and the exposure duration (ED) is 1 year (construction schedule). The body weight for an adult is 70 kilograms. For potential carcinogenic effects, the intake is averaged over a 70-year lifetime (AT = 25,550 d). For potential noncarcinogenic effects, the intake is averaged over the actual duration of exposure (AT = ED x 365 d). For the construction worker, the exposure duration is 1 year and averaged over 365 days. Substituting these values into Equation 6-7 yields:

$$I_{sd} = (1\ mg/kg)(5800\ cm^2/d)(10^{-6})(1\ mg/cm^2)(1x10^{-1})(250\ d/y)(1\ y)/(70\ kg)(25550\ d)$$

or (6-8)

$$I_{sd} = 8.10 \times 10^{-8}\ mg/kg\text{-}d$$

Appendix B presents the complete calculation sheets for dermal contact exposures.

TABLE 6-2
DERMAL ABSORPTION FACTORS (ABS)

COPC	ABS
1,1-dichloroethene	1.00E-01
1,2,4-trimethylbenzene	1.00E-01
1,3,5-trimethylbenzene	1.00E-01
aroclor 1248	1.00E-01
aroclor 1254	1.00E-01
aroclor 1260	1.00E-01
arsenic	3.00E-02
benzo(a)anthracene	1.50E-01
benzo(a)pyrene	1.50E-01
benzo(b)fluoranthene	1.50E-01
benzo(k)fluoranthene	1.50E-01
bis(2-ethylhexyl)phthalate	1.00E-01
chrysene	1.50E-01
dibenzo(a,h)anthracene	1.50E-01
fluoranthene	1.00E-01
indeno(1,2,3-cd)pyrene	1.50E-01
naphthalene	1.50E-01
n-butylbenzene	1.00E-01
n-propylbenzene	1.00E-01
p-cymene	1.00E-01
phenanthrene	1.50E-01
pyrene	1.50E-01
tetrachloroethylene	1.00E-01
trichloroethene	1.00E-01
xylenes	1.00E-01

SOURCE: Cal/EPA 1994

6.2 Risk Characterization Methodology

In this risk assessment, potential health effects to humans following exposure to site-related COPCs were estimated using methods established by EPA and Cal/EPA. Key documents used as guidance for preparing this risk assessment are presented in Section 1 and are referenced throughout the following paragraphs.

6.2.1 Health Effects Concepts for Quantitative Risk Assessment

In risk assessments, two different values are calculated to evaluate potential health impacts: the potential ILCR and the HI. The potential ILCR is an upper-bound estimate of the incremental cancer probability for individuals who may have been exposed to site-related COPCs. The potential ILCR is compared to a range of acceptable probabilities to determine whether the potential hazard poses an unacceptable health threat. The EPA currently uses an ILCR of 10^{-4} to 10^{-6} as the range of acceptable risks (EPA 1990b, 1991a).

The potential health effects resulting from exposure to noncarcinogenic hazardous COPCs are evaluated by comparing a receptor's exposure or intake level to the reference dose (RfD) of that COPC. The ratio of intake over the RfD is termed the hazard quotient (HQ) (EPA 1989a). An RfD is the daily exposure level likely to cause no appreciable risk of deleterious effects during a lifetime. If the HQ is greater than 1 or "above unity," there may be concern for potential noncarcinogenic health effects. The level of concern increases as the HQ increases above unity, although the two are not linearly related (EPA 1989a). When receptors are exposed to more than one COPC through multiple pathways, it is useful to develop a total HI. The HI is the summation of HQs across pathways (EPA 1986). The HI is also compared with a threshold level of unity.

6.2.2 Methods for Characterizing Health Effects

Risks from exposure to hazardous COPCs are calculated for carcinogenic and/or noncarcinogenic effects as appropriate. Some COPCs may pose both a toxic (noncarcinogenic) hazard and a

carcinogenic risk to receptors; risks from these COPCs are characterized for both types of health effects.

6.2.2.1 Carcinogenic Effects

The risk attributed to exposure to carcinogenic compounds is estimated as the probability of an individual developing cancer over a lifetime as a result of the exposure. At low doses, the risk (ILCR) of developing cancer is determined as follows (Cal/EPA 1992, EPA 1989a):

$$Risk = (CDI)(CSF) \qquad (6\text{-}9)$$

An exposed receptor's risk is presented as the potential ILCR and is calculated by multiplying the chronic daily intake (CDI) values for carcinogenic effects by the cancer slope factors (CSF) of the carcinogenic COPC (presented in Section 3). If a receptor is exposed via a pathway to several carcinogens, the following equation is used to sum cancer risks:

$$Risk_t = Risk\ (COPC_1) + Risk\ (COPC_2) + \ldots\ Risk\ (COPC_n) \qquad (6\text{-}10)$$

where

$Risk_t$	=	total risk of cancer incidence for a given pathway
$Risk(COPC_n)$	=	individual carcinogenic COPC risk

Similarly, if a receptor is exposed through multiple pathways, the total potential ILCR can be calculated by summing the pathway-specific risks (EPA 1986).

6.2.2.2 Noncarcinogenic Effects

As mentioned, the HQ is used to characterize the potential health effects resulting from exposure to noncarcinogenic, hazardous COPCs. The HQ compares a receptor's exposure or intake level to the RfD of that COPC (EPA 1989a) and is defined as:

$$HQ_i = CDI_i/RfD_i \qquad (6\text{-}11)$$

where

HQ_i = hazard quotient for $COPC_i$ (unitless)
CDI_i = chronic daily intake of $COPC_i$ (mg/kg-d)
RfD_i = reference dose of $COPC_i$ (mg/kg-d)

When using the above equation to estimate potential noncarcinogenic risk, both the intake and the RfD must refer to exposures of equivalent duration (e.g., chronic, subchronic, or fewer than two weeks). In this post-demolition risk assessment, COPC exposures were evaluated in all cases on a chronic basis (i.e., using chronic RfD values). HIs were determined by assuming dose additivity for those COPCs acting by the same mechanism and inducing the same effects (EPA 1986, 1989a). In the case of simultaneous exposure of a receptor to several COPCs, an HI was calculated as the sum of the HQs by:

$$HI_t = HQ(COPC_1) + HQ(COPC_2) + \ldots HQ(COPC_n) \qquad (6\text{-}12)$$

where

HI_t = total hazard index
$HQ(COPC_n)$ = individual noncarcinogenic COPC hazard

If the receptor is exposed through multiple pathways, the HI was calculated by first estimating the HQs for the COPCs in each exposure pathway and then summing the HQs to calculate a pathway-specific HI. Pathway HIs were then summed to produce a total HI specific to the receptor.

By summing the HQs across pathways and COPCs, it is assumed that all COPCs exhibit similar toxic properties and that those from different pathways manifest the same toxic effects. This is not usually the case, however. For example, the primary toxic effect of lead is to the central nervous system, while the primary toxic effects of ethylbenzene are irritation of the eyes and upper respiratory system. This is addressed further in Section 7.

6.3 Risks Posed by the Post-Demolition Exposure Scenarios

Table 6-3 presents the total HI and total ILCR results for each AOPC and receptor studied under the Parcel A post-demolition exposure scenarios. Because the reasonable maximum exposure (RME) approach was used to quantify potential health impacts, it should be noted that if the estimated health effects of the RME are within acceptable limits, then it is likely that all other, lesser exposures related to Parcel A are also within these limits. See Section 4.1.3 for more information on RME.

Each entry in the Table 6-3 is supported by detailed calculations of health effects by receptor, COPC, and pathway (see Appendix B).

TABLE 6-3
SUMMARY OF POST-DEMOLITION HEALTH RISK,
C-6 FACILITY, PARCEL A

On-Site Receptors	HI	ILCR
AOPC 1		
Construction Worker	5.1E-02	1.4E-06
Commercial/Industrial Worker, RME[a]	4.8E-02	9.3E-08
Commercial/Industrial Worker, Upper Bound[b]	5.3E-02	4.5E-06
AOPC 2		
Construction Worker	1.5E-02	7.7E-07
Commercial/Industrial Worker, RME[a]	4.8E-02	9.3E-08
Commercial/Industrial Worker, Upper Bound[b]	4.9E-02	2.6E-06
Off-Site Receptors	**HI**	**ILCR**
Commercial/Industrial Worker	2.5E-02	5.2E-08
Resident Adult	1.2E-03	2.9E-09
Resident Child	5.5E-03	2.7E-09

NOTES:
[a]Reasonable Maximum Exposure conditions, assumes 2-foot layer of clean fill.
[b]Upper Bound exposure conditions, assumes no layer of fill.

AOPC = Area of Potential Concern
HI = Hazard Index
ILCR = Incremental Lifetime Cancer Risk